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Theoretical Modelling and Meteorological Analysis for the AASE Mission

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Abstract:

Objective is to provide real time constituent data analysis and potential vorticity computations in support of the Airborne Arctic Stratospheric Experiment (AASE). NMC meteorological data and potential vorticity computations derived from NMC data are projected onto aircraft coordinates and provided to the investigators in real time. ER-2, balloon and satellite constituent data is composited into modified Lagrangian-mean coordinates. Various measurements are intercompared, trends deduced and reconstructions of constituent field performed.

Summary of Progress and Results:

The real time data objectives were met during the Norway AASE mission and meteorological data files were provided to the investigators in Norway. Improvements in the analysis were made after the mission, and updated files have been provided to the archive at NASA Ames. Demand for the data sets has been high as the meteorological data has been crucial in determining the location of the polar vortex and interpreting the DC-8 column constituent data. Meteorological data analysis is now being extended to cover the previous AAOE mission period (August-September, 1987) so that potential vorticity data sets will be available for both missions.

The reconstruction and modified Lagrangian mean transformation procedure has proven to be a powerful tool for the extension and intercomparison of constituent data sets. Recently the DIAL lidar, ER-2 insitu and ozonesonde measurements taken at different locations have been directly compared with suprisingly good agreement.

In addition to this work, analysis of meteorological and total ozone data projects have continued. This analysis includes characterizing the effect of the QBO in modulating the Antarctic ozone depletion, comparison between the 1988 and 1987 southern hemisphere depletions, and analysis of long term trends in ozone and temperature from NMC data. Additional research on gravity wave propagation and breakdown has also been performed.

Publications:

Antarctic springtime ozone depletion computed from temperature observations, J. E. Rosenfield, M. R. Schoeberl, and P. A. Newman, J. Geophys. Res., 93, 3833-3849, 1988.

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Effect of self-consistent horizontal diffusion coefficients on 2-dimensional N_2O model distributions, C. H. Jackman, P. A. Newman, P. D. Guthrie, and M. R. Schoeberl, J. Geophys. Res., 93, 5213, 1988.

The role of gravity wave generated advection and diffusion in transport of tracers in the mesosphere, J. R. Holton and M. R. Schoeberl, in press, J. Geophys. Res., 1988.

Mixing rates calculated from potential vorticity, P. A. Newman, M. R. Schoeberl, R. A. Plumb, and J. E. Rosenfield, J. Geophys. Res., 93, 5221, 1988.

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Breakdown of vertically propagating gravity waves forced by orography, J. T. Bacmeister and M. R. Schoeberl, J. Atmos. Sci., 46, 2109-2134, 1989.

The 1988 Antarctic ozone depletion: Comparison with previous year depletions, M. R. Schoeberl, R. S. Stolarski, and A. J. Krueger, Geophys. Res. Lett., 16, 377-380, 1989.

Quasi-biennial modulation of the Antarctic ozone depletion, L. R. Lait, M. R. Schoeberl, and P. A. Newman, J. Geophys. Res., 1989.

Reconstruction of the constituent distribution and trends in the Antarctic polar vortex from ER-2 flight observation, M. R. Schoeberl, L. R. Lait, M. Proffitt, P. A. Newman, R. L. Martin, D. L. Hartmann, M. Loewenstein, J. Podolske, S. E. Strahan, J. Anderson, K. R. Chan, B. Gary, J. Geophys. Res., in press, 1989.

Potential vorticity estimates in the south polar vortex from ER-2 flight data, D. L. Hartmann, K. R. Chan, B. L. Gary, M. R. Schoeberl, P. A. Newman, R. L. Martin, M. Loewenstein, J. R. Podolske, S. E. Strahan, J. Geophys. Res., 1989.

Evidence of the mid-latitude impact of Antarctic ozone depletion, R. J. Atkinson, W. A. Mathews, P. A. Newman, R. A. Plumb, Nature, 340, 290-294, 1989.

THE INTERACTION OF SOLAR ULTRAVIOLET RADIATION (280-400 NM) WITH THE TERRESTRIAL SYSTEM

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RESEARCH OBJECTIVES:

This research is devoted to examining the role of the stratosphere, and to a lesser extent the troposphere, in determining the ultraviolet radiation levels incident on the biosphere. The approach combines radiative transfer calculations (which include multiple Rayleigh scattering, absorption by an arbitrary number of gases, scattering within clouds, and reflection from a lower boundary) with measurements of atmospheric composition.

PROGRESS AND RESULTS (1988-89):

Results published in 1988 showed that variations in local cloudiness of plus or minus 10% at middle latitudes could lead to changes in surface ultraviolet radiation as great as those predicted from trends in ozone since 1970. Analyses performed for the Scientific Assessment of Stratospheric Ozone: 1989 demonstrate that trends in ozone of the magnitude derived from Dobson measurements would not appear in a straightforward manner in the data record acquired by the Robertson-Berger (RB) meter network. There is therefore no inconsistency between the derived decline in ozone over middle latitudes of the Northern Hemisphere and the failure of the RB meters to observe increased ultraviolet irradiance at the ground. Effects of local cloudiness and of localized sources of air pollution can be major factors in determining trends in the RB meter output.

In other research supported under this grant we examined the impact of the springtime Antarctic ozone depletion on the surface ultraviolet radiation environment of the region. As one proceeds from September through December surface radiation level increase in response to the natural change in solar elevation. However, the presence of a large ozone depletion in October leads to ultraviolet irradiances similar to or greater than those at summer solstice. The effect of the ozone hole is therefore to extend the duration of summerlike ultraviolet radiation levels. Any persistence of the ozone depletion as summer approaches would be especially significant here.

JOURNAL PUBLICATIONS (1988-89):

Frederick, J. E., and D. Lubin, The budget of biologically active ultraviolet radiation in the earth-atmosphere system, J. Geophys. Res., 93, 3925-3832, 1988.

Frederick, J. E., and H. E. Snell, Ultraviolet radiation levels during the Antarctic spring, Science, 241, 438-440, 1988.

Lubin, D., J. E. Frederick, and A. J. Krueger, The ultraviolet radiation environment of Antarctica: McMurdo Station during September-October 1987, J. Geophys. Res., 94, 8491-8496, 1989.

Research Summary (1988)

A. Title of Research Task:

A Correlative Study of SME Ozone Observations and Ground-based Microwave Water Vapor Measurements

B. Investigators and Institutions:

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C. Abstract of Research Objectives:

The major objective of the study is to employ Solar Mesosphere Explorer (SME) ozone and solar flux measurements, along with ground-based microwave water vapor measurements, in order to study the photochemistry of the mesosphere. Water vapor is the climatological variable most important in controlling ozone concentrations in the mesosphere because it is the predominant source of odd hydrogen which (through the odd hydrogen catalytic cycle) dominates ozone loss in the mesosphere. By analysis of the water vapor and ozone data, and interpretation with a 1-D photochemical model, we intend to provide a more complete understanding of the vertical distribution of ozone in the mesosphere. In addition, the measured water vapor profiles will be used with the 1-D model to investigate vertical transport processes and time-scales in the mesosphere.

D. Summary of Progress and Results:

We have analyzed three years of ground-based microwave water vapor measurements obtained at Penn State. The observations indicate that the seasonal variation of water vapor in the upper mesosphere is dominated by an annual variation with low abundances in winter and high abundances in summer. This suggests that advection dominates diffusion in establishing the vertical distribution of water vapor in the mesosphere, and is consistent with the steep vertical gradient in the water vapor mixing ratio profile persistently observed in the upper mesosphere. However, it is very difficult to reconcile the annual water vapor variation with the predominantly semiannual variation of ozone in the upper mesosphere observed by SME. In fact, we have performed a series of 1-D photochemical model calculations which verify that (within the context of the hydrogen/oxygen chemistry considered in the model), the seasonal variation of water vapor cannot be the mechanism for the semiannual ozone variation. This variation is either a manifestation of some heretofore unknown photochemical mechanism; or, it could be driven by a seasonal variation in the vertical transport of atomic oxygen from the thermosphere.

We have also modeled the diurnal variation of ozone in the mesosphere and compared this to measurements made by ground-based microwave techniques at Bern Switzerland in the winter and spring of 1987. We find that the 1-D model calculations accurately reproduce the relative diurnal ozone variation at equinox, suggesting that the ozone photolysis rate coefficient is accurate to better than 10%. However, in winter the model underpredicts the observed relative diurnal variation by a factor of 2, with the major part of this discrepancy resulting from the observed post midnight increase in ozone which is not obtained in the model.

Finally, we have used our 1-D photochemical model, along with a time-dependent heat equation, to study the response of mesospheric ozone concentrations to short-term uv solar flux variations. The model results have been compared with the observed ozone response obtained from a statistical analysis of SME ozone measurements. We find that the model with sinusoidal forcing of mesospheric chemistry by solar uv flux variations with a period of 27 days, combined with temperature-chemistry feedback and time dependent atmospheric temperature effects, reproduces the major characteristics of the observed ozone response. However, we also find that the magnitude of the computed ozone response in the upper mesosphere (above 70 km) to increased solar uv flux is strongly coupled to the water vapor abundance through the odd hydrogen catalytic cycle which removes ozone. Therefore, as a consequence of the observed seasonal variation of water vapor in the upper mesosphere, we predict a significant seasonal variation of the magnitude of the ozone response to solar uv flux variations.

E. Journal Publications:

1) Bevilacqua, R. M., J. J. Olivero, and C. L. Croskey, Mesospheric water vapor measurements from Penn State: monthly mean observations (1984-1987), J. Geophys. Res., in press, 1989.

2) Zommerfelds, W. C., K. F. Kunzi, M. E. Summers, R. M. Bevilacqua, D. F. Strobel, M. Allen, and W. J. Sawchuck, Diurnal variations of mesospheric ozone obtained by ground-based microwave radiometry, J. Geophys. Res., in press, 1989.

3) Bevilacqua R. M., D. F. Strobel, M. E. Summers, J. J. Olivero, and M. Allen, The seasonal variation of water vapor and ozone in the upper mesosphere: implications for vertical transport and ozone photochemistry, J. Geophys. Res., submitted, 1989.

4) Summers, M. E., R. M. Bevilacqua, D. F. Strobel, M. T. DeLand, M. Allen, and G. M. Keating, A model study of the response of mesospheric ozone to short-term solar ultraviolet flux variations, J. Geophys. Res., submitted, 1989.